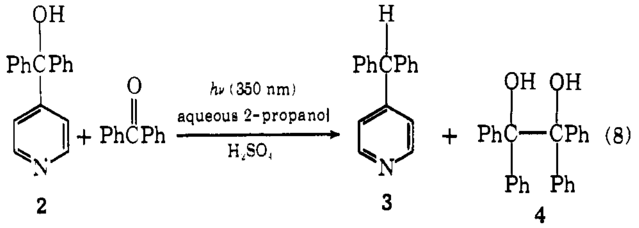
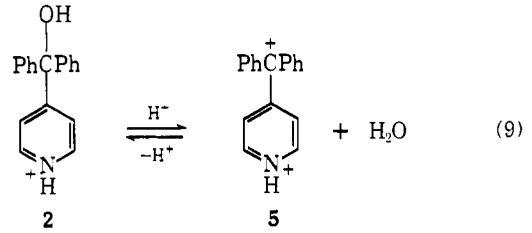
form and are presently under investigation. These are highly polar substances which contain neither cyano nor benzhydryl groups. Pyridine or unreacted 4-cyanopyridine could not be detected among the reaction products.

Though dimethyl ketyl can also transfer electrons to suitable acceptors very efficiently,[9] in this reaction, concentration factors should favor diphenyl ketyl as the transfer agent.[10]

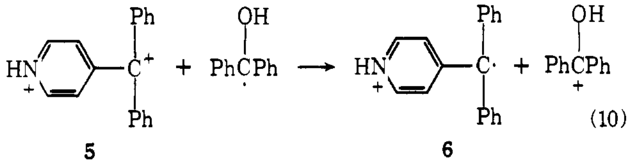
4-Benzhydrylpyridine (**3**) is not a primary product of reaction but has been shown to form in 71% yield when **2** is irradiated in acidic aqueous 2-propanol under the same conditions as described for **1** (eq 8). In acid solution, if an equilibrium is established between protonated **2** and carbonium ion **5** (eq 9), then an electron would most likely transfer directly to the carbonium ion center of **5** (eq 10) forming the radical **6** which would subsequently form **3** by hydrogen atom abstraction. Even if the equilibrium in eq 9 is unfavorable, the formation of the more stable radical **6** would be rapid since the electron exchange (eq 10) should occur at a diffusion controlled rate.[11]



(8)

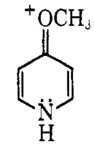


(9)



(10)

Preliminary results indicate, furthermore, that the electron transfer step is very sensitive to both the electron donor capacity of the substituent on the pyridine ring as well as the steric hindrance about the ketyl donor radical. This is demonstrated by the facts that 4-methoxypyridinium ion does not react with diphenyl ketyl, presumably because of the considerable ground state contribution from structure **7**,[1,12] and duryl phenyl ketyl[13] does not react with 4-cyanopyridinium ion.



7

Pyridinyl radicals are known to dimerize or disproportionate by second-order kinetics.[9] Though there is some infrared evidence for the presence of 4,4′-dipyridyl among the reaction products, under the conditions used, dimerization does not appear to be a major pathway.

We are presently studying these reactions by ESR and investigating the reaction of diphenyl ketyl with other substituted pyridinium ions and other molecules, and these will be subjects of subsequent reports.

Acknowledgment. We would like to thank Professor Philip Rieger and Dr. Nancy Rieger, Department of Chemistry, Brown University, for the determination of the ESR spectra used in this study and the Reilly Tar and Chemical Corporation for generous samples of substituted pyridines.

References and Notes

(1) For a review of this subject see F. Minisci and O. Porta, *Adv. Heterocycl. Chem.*, **16**, 123 (1974).
(2) F. Minisci, R. Mondelli, G. P. Gardini, and O. Porta, *Tetrahedron*, **28**, 2403 (1972).
(3) (a) J. N. Pitts, Jr., H. W. Johnson, and T. Kuwana, *J. Phys. Chem.*, **66**, 2456 (1962); (b) J. N. Pitts, Jr., R. L. Letsinger, R. P. Taylor, J. M. Patterson, G. Recktenwald, and R. B. Martin, *J. Am. Chem. Soc.*, **81**, 1068 (1959); (c) H. L. J. Bäckström, K. L. Appelgen, and R. J. V. Niklassen, *Acta Chem. Scand.*, **19**, 1555 (1965).
(4) The mechanism for the formation of diphenyl ketyl shown here is oversimplified. The precise mechanism, however, is still in doubt. For a more complete discussion see N. Filipescu and F. L. Minn, *J. Am. Chem. Soc.*, **90**, 1544 (1968), and S. A. Weiner, *ibid.*, **93**, 425 (1971).
(5) The absence of oxygen is not a stringent requirement in this reaction.
(6) The ESR spectrum of **1** taken under the same reaction conditions showed the absorption of a short lived radical centered at approximately $g = 2.0$. The signal extended 25 G from end to end and clearly showed a rich hyperfine structure which could not be resolved because of low concentration. The spectrum disappeared as soon as the light was extinguished.
(7) A. E. Tschitschibabin and S. W. Benewolenskaja, *Chem. Ber.*, 547 (1928).
(8) Analyses by mass and nuclear magnetic resonance spectroscopy were consistent with the assigned structures.
(9) P. Neta and L. K. Patterson, *J. Phys. Chem.*, **78**, 2211 (1974), and references therein.
(10) If the mechanism proposed by Filipescu (ref 4) is correct then there would be very little dimethyl ketyl free in solution.
(11) The rate constant of electron exchange between diphenyl ketyl and benzophenone is approximately $10^8\ M^{-1}\ \mathrm{sec}^{-1}$ (N. Hirota and S. R. Weissman, *J. Am. Chem. Soc.*, **86**, 2537 (1964)). Electron transfer to a reactive positive center should occur at a still faster rate.
(12) M. L. Belli, G. Illuminati, and G. Marino, *Tetrahedron*, **19**, 345 (1963).
(13) For duryl phenyl ketone the absolute quantum yield for photoreduction by 2-propanol is 0.04 (F. A. Lamb and B. M. Vittimberga, *J. Org. Chem.*, **38**, 3520 (1973)).

Bruno M. Vittimberga*
Department of Chemistry, University of Rhode Island
Kingston, Rhode Island 02881

Francesco Minisci, Sergio Morrocchi
Istituto di Chimica, Politecnico
Milan, Italy

Received February 10, 1975

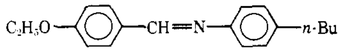
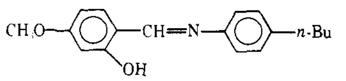
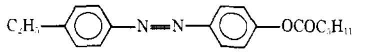
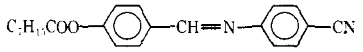
Effects of Molecular Complexing on the Properties of Binary Nematic Liquid Crystal Mixtures

Sir:

In order to achieve extended liquid crystalline temperature ranges, binary systems offer the advantage of frequently exhibiting eutectic behavior in their solid → mesophase transition while the mesophase → isotropic transition temperature varies linearly with composition. In particular, several binary nematic systems have been studied,[1-7] and only small deviations from linearity in the nematic → isotropic transition temperatures (T_{NI}) are noted when there are significant differences in molar volumes or densities of the components. This general behavior has been satisfactorily accounted for theoretically by Humphries and Luckhurst.[8]

It seemed to us that large deviations in T_{NI} as well as the solid → nematic transition temperature (T_{SN}) should be possible if molecular complex formation took place between the components of the binary system. Further, as opposed to the usual deviations in T_{NI} being depressions of the melting point,[9] in the case of complex formation, *increases* in the

Table I. Positive Deviations in T_{NI} for Binary Nematic Mixtures of CPB (Nematic Range 23.5–35.0°) and a Nematic Donor

Nematic donor	Nematic range of donor, °C	Mole % CPB	Nematic range of mixture, °C	ΔT_{NI}, °C
MBBA	20.9–43.5	46.0	37.5–49.2	+9.6
	35.0–75.4	50.5	61.0–64.5	+9.5
	44.0–62.6	50.9	15.0–53.0	+4.5
	72.0–126.0	53.0	60.0–86.4	+8.6
	52.0–94.5	54.8	19.6–64.8	+2.9

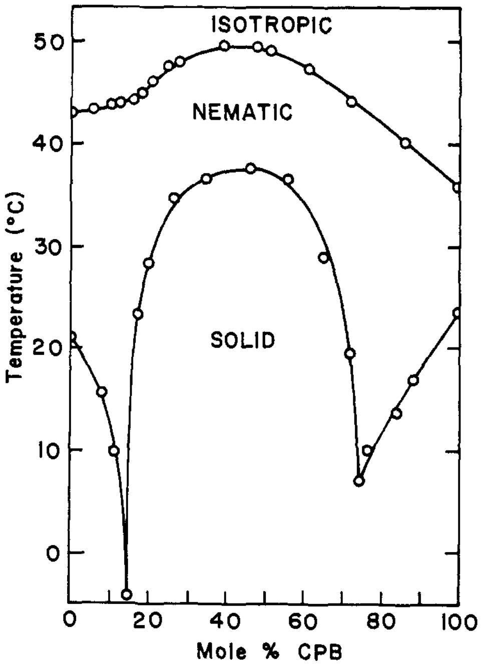


Figure 1. Phase diagram of MBBA-CPB.

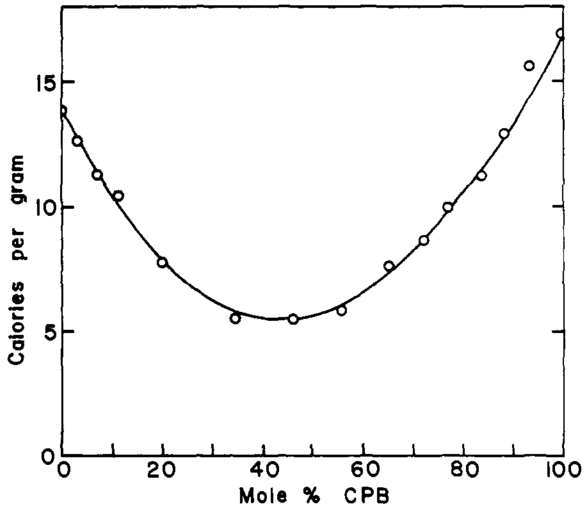


Figure 2. Heat of solid → nematic transition vs. mole % of CPB.

melting point over either component of the system could occur. We have achieved this result in the binary system *N*-(*p*-methoxybenzylidene)-*p*-*n*-butylaniline (MBBA) and 4-cyano-4′-pentylbiphenyl (CPB) and several closely related binary mixtures.

MBBA and CPB were chosen[10] because of the possibility of a weak charge-transfer interaction between the components. Spectroscopic studies in the nematic phase of a 50–50 mole % binary mixture show a typical broad weak absorption band in the visible peaking at ~550 nm. The phase diagram (Figure 1) was determined using both polarized optical microscopy on a Mettler FP-2 hot stage and differential scanning calorimetry (DSC) utilizing a Perkin-Elmer DSC 1-B. DSC determinations were done on a heating cycle on samples which had been refrigerated at −20° for at least 5 days to avoid supercooled samples.

With regard to T_{SN}, the phase diagram is a classical example of a two-component system forming a compound, displaying a congruent melting point, and exhibiting two eutectics. T_{NI} shows a maximum at a temperature ~10° higher than expected for a linear relationship between the clearing points of the two components. The T_{NI} and T_{SN} maxima occur at ca. 50–50 mole % of MBBA-CPB. Enthalpies of the solid–nematic transition (ΔH_{SN}) for the binary mixture are plotted in Figure 2, showing minimal values of ΔH_{SN} at compositions close to the 50–50 mixture. Similar positive deviations in T_{NI} are seen in mixtures of other Schiff bases or a nematic with a central azo linkage functioning as donor moieties with CPB functioning as the acceptor and are listed in Table I.

By virtue of charge-transfer interaction of components of a binary mixture, it is clear that extended liquid-crystalline temperature ranges can be achieved. The interaction also was expected to lead to nonlinearities in dielectric properties and possible modulation of electrooptical properties. Dielectric anisotropies were evaluated by measuring dielectric constants on aligned nematic samples, holding the orientation of the nematic director in a 15 kOe magnetic field.[11] Twisted nematic cells were constructed using SiO treated glass plates and 50 μ spacers to allow study of delay times, rise times, decay times, and threshold voltages (V_{th}) for electric field addressing in a manner previously described.[12]

Strong positive deviations in the value of $\Delta\epsilon$ ($=\epsilon_{\parallel} - \epsilon_{\perp}$) were observed. A 50–50 mole % MBBA-CPB mixture has a $\Delta\epsilon$ of 7.7 whereas a simple additivity law implies a value of 5.8. The delay time decreases by a factor of 2 in going from 100% CPB to the 50–50 mixture, but rise times, decay times, and V_{th} are relatively insensitive to composition.

It therefore appears quite likely that, in addition to extending nematic ranges by involving complexing between the components of a binary mixture, one can cause changes in dielectric anisotropies, viscosities, and elastic constants which will affect electrooptic behavior in these systems. Attempts to design appropriate systems to take maximum advantage of nonlinearities in their properties are in progress.

Acknowledgment. This work was supported by the U.S. Army Research Office (Durham) under Grant No. DAHC04-74-G-0186.

References and Notes

(1) J. S. Dave and M. J. S. Dewar, *J. Chem. Soc.*, 417 (1954); 4305 (1955).
(2) R. Steinsträsser and L. Pohl, *Z. Naturforsch., Teil B*, **26**, 87 (1971).
(3) L. Pohl and R. Steinsträsser, *Z. Naturforsch. Teil B*, **26**, 26 (1971).
(4) R. A. Bernheim and T. A. Shuhler, *J. Phys. Chem.*, **76**, 925 (1972).
(5) J. Homer and A. R. Dudley, *J. Chem. Soc., Chem. Commun.*, 926 (1972).
(6) H. Arnold and H. Sackmann, *Z. Phys. Chem. (Leipzig)*, **213**, 145 (1960).
(7) E. C. H. Hsu and J. F. Johnson, *Mol. Cryst. Liq. Cryst.*, **20**, 177 (1973); **27**, 95 (1974).
(8) R. L. Humphries and G. R. Luckhurst, *Chem. Phys. Lett.*, **23**, 567 (1973).
(9) The only exception is a binary mixture of *n*-butyl-*p*-(*p*-ethoxyphenoxycarbonyl)phenylcarbonate and (*p*-ethoxyphenylazo)phenylheptanoate reported in ref 3 and 4; nematic ranges for the pure components are inconsistent in these two reports, and a positive deviation in T_{NI} for a 60–40 mole % mixture of between 16 and 4° is implied. It is doubtful that these two compounds were sufficiently pure to make the result meaningful.
(10) MBBA and CPB are both available commercially in special highly purified grades suitable for electrooptic studies from Eastman Kodak Co. and Atomergic Chemetals Co., respectively.
(11) A. I. Baise and M. M. Labes, *Appl. Phys. Lett.*, **24**, 298 (1974).
(12) C. S. Bak, K. Ko, and M. M. Labes, *J. Appl. Phys.*, **46**, 1 (1975).

J. W. Park, C. S. Bak, M. M. Labes*
Department of Chemistry, Temple University
Philadelphia, Pennsylvania 19122

Received April 15, 1975

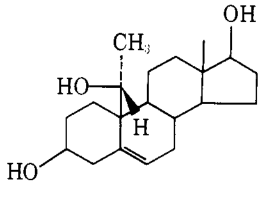
Reassignment of the Absolute Configuration of 19-Substituted 19-Hydroxysteroids and Stereomechanism of Estrogen Biosynthesis

Sir:

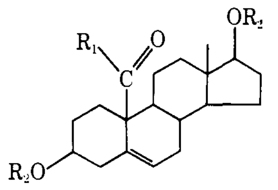
We wish to report evidence for reversing the previous assignment of the absolute configuration at the C-19 position of 19-hydroxy-19-methylandrost-5-ene[1] and of other structures[2] fundamentally dependent on it for their stereochemical assignments.[3] Using numerous reaction sequences and stereochemical considerations of the hypothesis of Karabatsos,[4] a modification of Cram's rule,[5] of Cherest et al,[6] and of relative rates of 3,19-oxide formation over A-ring Wicha and Caspi[1] assigned the 19*R* configuration for the only isolated (90% yield) 3*β*,17*β*,19-trihydroxy-19-methylandrost-5-ene (I) from methyllithium reaction with 3*β*,17*β*-diacetoxy-5-androsten-19-al (**2a**) and 19*S* (**3**) for the only isolated alcohol obtained by lithium aluminum hydride reduction of 3*β*,17*β*-diacetoxy-19-methylandrost-5-en-19-one (**2b**). Based on Wicha and Caspi's studies, Skinner and Akhtar[2a] tentatively assigned the 19*R*-^{3}H configuration to the major product of ^{3}H-labeled sodium borohydride reduction of the aldehyde **2c**. They proposed that in estrogen biosynthesis the 19-hydroxylation of the 19-hydroxyandrogen occurs at the 19pro*S* hydrogen.[2a] Contrary to this mechanism we proposed[7] stereospecific 19pro*R* hydrogen removal in enzymic aromatization of 19-hydroxytestosterone, which is a more direct precursor for estrogen biosynthesis than a Δ^5-3*β*-ol,[8] based on the assignment of 19*S*-^{3}H configuration to the major product (90% pro*S*/10% pro*R*) of the labeling of Δ^4-3-oxo-19-al.

To reconcile the apparent conflict for the stereomechanism of enzymic aromatization the following are considered: (1) stereospecificity of the 19-hydroxylation by human placental androgen aromatase could be opposite for the substrates 19-hydroxy-Δ^5-3*β*-ol or 19-hydroxy-Δ^4-3-one; (2) stereoselectivity of the nucleophilic attack of methyllithium and sodium borohydride on the steroidal 19-aldehyde could be different enough to make the tentative assignment by Skinner and Akhtar invalid; or (3) either one of the two assignments must be reversed.

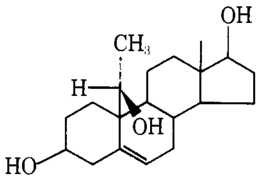
We have carried out further conformational studies using X-ray crystallography, isotope labeling, NMR, and enzymic reactions. We report here that the stereoselectivity of the two nucleophilic reactions at the 19-aldehyde is similar, estrogen biosynthesis is by stereospecific removal of the 19pro*R* hydrogen of both the 19-hydroxylated Δ^5-3*β*-ol and Δ^4-3-one systems, and the previous configurational assignment[1,2] of 19-substituted 19-hydroxy-steroids should be reversed.



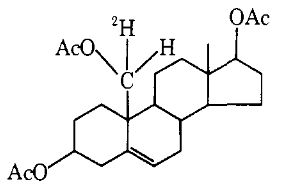
1



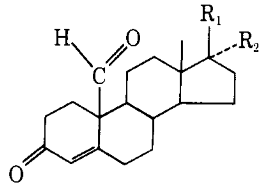
2a, $R_1 = H$; $R_2 = Ac$
b, $R_1 = CH_3$; $R_2 = Ac$
c, $R_1 = R_2 = H$



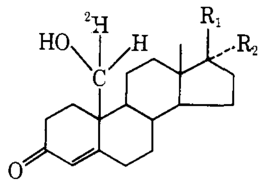
3



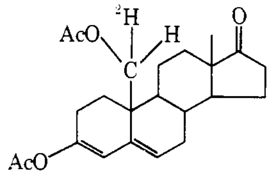
4



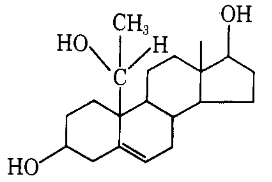
5a, $R_1 = OCOC_6H_5$; $R_2 = H$
b, $R_1, R_2 = O$



6a, $R_1 = OCOC_6H_5$; $R_2 = H$
b, $R_1, R_2 = O$



7



11

The aldehyde **2a** was reduced with deuterium labeled (>98% ^{2}H) sodium borohydride in methanol and the resulting alcohol was acetylated to give [19-^{2}H]-3*β*,17*β*,19-triacetoxyandrost-5-ene (**4**): mp 88–90°; ir 1735, 1240, 1030 cm^{-1}; ^{1}H NMR (60 MHz), *δ* 0.83 (18-CH_3, 3 H, s), 2.03 (OAc, 9 H, s). Quantitative analysis by ^{1}H NMR at 300 MHz,[9] as shown in Figure 1, gave 67% ^{2}H labeling at the higher field 19-proton (*δ* 3.96 ppm) and 33% at the lower field 19-proton (*δ* 4.49). 17*β*-Benzoyloxy-3-oxo-4-androsten-19-al (**5a**)[10] was similarly reduced with sodium borodeuteride to give [19-^{2}H]-19-hydroxytestosterone 17-benzoate (**6a**),[7,11] mp 242–245°. Analysis of the 19-protons by 300-MHz ^{1}H NMR showed 90% ^{2}H labeling at the lower field (*δ* 4.06) and 10% at the higher field proton (*δ* 3.89) in **6a** as in Figure 2. In order to establish the stereochemical relationships of the labels in the two systems, transformation of [19-^{2}H]-Δ^4-3-one to [19-^{2}H]-Δ^5-3*β*-ol was carried out without removal of the label. 3,17-Dioxo-4-androsten-19-al (**5b**)[12] was selectively reduced with sodium borodeuteride to afford [19-^{2}H]-19-hydroxy-4-androstene-3,17-dione (**6b**): mp 168–170°; ir, 3300, 1737, 1658, 1618 cm^{-1}; ^{1}H NMR ($CDCl_3$-D_2O), *δ* 0.92 (18-CH_3, 3 H, s), 5.91 (4-H, 1 H, s); 90% ^{2}H labeling at the lower field 19-H and 10% ^{2}H at the higher field 19-H as observed in **6a**. The unsaturated ketone was treated with acetic anhydride and perchloric acid to give [19-^{2}H]-3,19-diacetoxyandrosta-3,5-dien-17-one (**7**) as an oil. The enol acetate was